TRANSLATION

2/PRTS

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Specification

Transistor

The invention relates to a transistor with an emitter, a collector, and a base layer.

Transistors of the type noted above are known from the publication "SiGe Bipolar Technology for Mixed Digital and Analog RF Applications," J. Böck et al., *IEEE 2000,* in which the base layer has an intrinsic segment and an extrinsic segment, where the extrinsic segment connects a base contact with the intrinsic segment. The extrinsic segment has a relatively low boron doping, so that the known transistor has the disadvantage of a high resistance in the base layer. This leads to a drop in power amplification already at low frequencies, and thereby to an effective slow-down of the transistor. In addition, the higher base feed resistance causes greater noise.

It is the goal of the present invention to provide a transistor where the base layer has a low ohmic resistance.

This goal is achieved by means of a transistor according to claim 1. Advantageous embodiments of the transistor are shown in the dependent claims.

A transistor is disclosed that has an emitter, a collector, and a base layer. The emitter extends into the base layer. The base layer has an intrinsic region arranged between the emitter and the collector. Furthermore, the emitter has an extrinsic region that runs between a base contact and the intrinsic region of the base layer. The base layer contains a first doping layer that runs within the base layer, which is doped with a trivalent doping substance. The first doping layer extends into the extrinsic region and also runs in the region of the emitter, where it is counter-doped with a pentavalent doping substance.

The transistor has the advantage that doping of the base layer can be undertaken via the first doping layer, which extends into the extrinsic region and also runs into the emitter, thereby advantageously reducing the ohmic resistance of the base layer. In this way, electrical losses of the transistor can be reduced.

Because the first doped layer runs both in the extrinsic region of the base layer and in the region of the emitter, it can be produced via usual methods for doping base layers, without any additional structuring step. Usual methods are: doping by means of implantation, as well as epitactic depositing.

Via the doping, additional charge carriers in the form of holes in the base layer are made available, thereby increasing the conductivity of the base layer. In this way, the ohmic resistance between the base contact, where the base layer is contacted from the outside, and the intrinsic base is reduced.

Advantageously, boron can be selected as a trivalent doping substance for the first doping layer. Boron has the advantage that its activation energy of the holes is the lowest of all trivalent doping substances. As a result, doping with boron already works at room temperature.

Additional doping layers can be arranged between the first doping layer and the collector. A second doping layer and a third doping layer are envisioned, for example. The second doping layer is arranged between the first doping layer and the third doping layer. The second and third doping layers are each doped with a trivalent doping substance, preferably boron. The doping-substance concentration of the second doping layer is less than the doping-substance concentration of the first and third doping layers.

The low doping-substance concentration of the second doping layer has the advantage that in this way, the PN transition on the base side comes to rest in a region with a low doping-substance concentration. In this way, the emitter/base leakage current on the basis of the tunnel effect is reduced, on the one hand, and, on the other hand, the parasitic emitter/base capacitance is minimized.

The pentavalent doping within the base layer can be diffused into the base layer from an emitter region that borders on the base layer. This diffusion of a pentavalent doping substance from the emitter region into the base layer is advantageous, since in this

way, the PN transition can be shifted from a polycrystalline silicon, usually used for the emitter region, to a region of the base layer having crystalline silicon. This has the result that the PN transition lies in a region having few interference locations, and for this reason, the resulting transistor has a better direct-voltage characteristic, with good linearity of the amplification.

In the following, the invention will be explained in greater detail, using an example embodiment and the related diagrams.

Figure 1 shows a silicon substrate with a transistor, in schematic cross-section.

Figure 2 shows the concentration progression of doping substances along line A in Figure 1.

Figure 1 shows a silicon substrate having a base layer 3. An emitter region 11 is arranged above the base layer 3. A collector is arranged below the base layer 3. The base layer 3 has an intrinsic region 4 that lies between the collector 2 and the emitter 1 of the transistor. The emitter 1 is formed from the emitter region 11 and a region that has a counter-doping substance 8, which is diffused into the base layer 3 from the emitter region 11. The broken line in Figure 1 shows the edge of the counter-doping substance 8.

The base layer 3 furthermore comprises an extrinsic region 6 that runs between a base contact 5 and the intrinsic region 4.

Furthermore, a first doping layer 7, which runs within the extrinsic region 6 and also within the emitter 1, is envisioned in the base layer 3. The first doping layer 7 is preferably produced by doping with boron. Measured according to a depth scale that begins at the top end of the arrow A (at t0), the first doping layer 7 begins at a depth t1. It extends to a depth t2. In the region between the emitter region 11 and the collector 2, the first doping layer 7 lies completely within the emitter 1. A second doping layer 9 is connected to the first doping layer 7. The second doping layer 9 extends from depth t2 to depth t4. The second doping layer 9 has a lower doping than the first doping layer 7. The second doping layer 9 is connected to a third doping layer 10. The third doping layer 10 extends from depth t4 to depth t5. The collector 2 then begins at depth t5. The third doping layer 10 has a higher doping than the second doping layer 9. Preferably, all three doping layers 7, 9, 10 are produced by the doping substance boron.

On the depth scale along the line A, the counter-doping substance 8 extends to depth t3, which means that the counter-doping substance 8 still extends into the second doping layer 9.

Figure 2 shows the dependence of dopings on concentration along the line A in Figure 1. Here, the doping-substance concentration C is plotted as a function of the depth t. C4max represents the maximal doping-substance concentration of the counter-doping substance 8 in the region of the base layer 3. Depth t0 marks the boundary between the

emitter region 11 and the base layer 3. This is, at the same time, the boundary between a silicon material that is present in polycrystalline form (emitter region 11) and in monocrystalline form (base layer 3). The first doping layer 7 begins at a distance from this boundary layer between the emitter region 11 and the base layer 3. The first doping layer 7 has a doping substance concentration C1 that is essentially constant over the layer thickness t2 – t1. The doping substance concentration C1 is preferably between 1×10^{18} and 5×10^{20} cm^{-3}. The thickness t2 – t1 of the first doping layer 7 is preferably between 10 and 100 nm.

Directly connected to the first doping layer 7 is the second doping layer 9. The doping-substance concentration in the second doping layer 9 is essentially constant and corresponds to the doping-substance concentration C2. C2 preferably lies between 1×10^{18} and 1×10^{19} cm^{-3}. The thickness t4 – t2 of the second doping layer 9 is selected in such a manner that at least half of the second doping layer 9 still lies within the region delimited by the counter-doping substance 8 and the outer boundary of the region that represents the emitter 1. This is advantageous for realizing a low parasitic emitter/base capacitance.

The third doping layer 10 still lies next to the second doping layer 9. The third doping layer 10 has a thickness t5 – t4, which typically amounts to 5 to 50 nm. The doping substance concentration C3, which is essentially constant within the third doping layer 10, is preferably between 5×10^{18} and 1×10^{20} cm^{-3}.

In this regard, it is particularly advantageous if the doping substance concentration C1 of the first doping layer 7 has a sizable proportion of the total amount of doping substance in the base layer 3. In this way, it can be assured that the first doping layer 7 makes a significant contribution to the conductivity of the base layer 3. It is advantageous if the proportion of the first doping layer 7 comprises 30% or more of the total amount of doping substance that is determined by the first doping layer 7, together with the second doping layer 9 and the third doping layer 10.

The reference symbols indicated in the lower part, below the abscissa, as well as in the upper part of Figure 2, correspond to the reference symbols used in Figure 1 for the individual layers.

Furthermore, the counter-doping substance 8 can be seen in Figure 2; it proceeds from a maximal doping-substance concentration C4max and at first remains constant with increasing depth, and then decreases greatly, approximately at the bottom edge of the first doping layer 7, and finally is reduced to zero within the second doping layer 9. The counter-doping substance 8 marks the outermost edge of the emitter 1. It has the effect that the first doping layer 7 present in the base layer 3, which increases the ohmic resistance of the extrinsic base, does not have any negative effects in the intrinsic part of the transistor. Here, the counter-doping is designed in such a way that the doping of the first doping layer 7 is at least compensated, and preferably is actually over-compensated.

Depending on the boundary between the emitter 1 and the intrinsic region 4 of the base, the intrinsic region 4 extends approximately between the depth t5 and the depth t3, while the emitter 1 extends between the depth t3 and the left edge of Figure 2. The monocrystalline base layer delimits the emitter region vertically. Laterally, it is defined via photolithography, so that the diffusion of As is effective only in the intrinsic region.

In Figure 2, a germanium doping 12 can also be seen, which decreases, proceeding from the collector 2, towards the base. By means of such a ramp-shaped germanium doping 12, an acceleration of the charge carriers penetrating into the base from the collector 2 can take place, and this increases the speed of the transistor.

The maximal doping substance concentration of the counter-doping substance 8, C4max, is preferably in the range between 1×10^{20} and 1×10^{21} cm^{-3}. Preferably, arsenic is used as the counter-doping substance 8. This arsenic is diffused into the base layer 3 from the emitter region 11.

It is also advantageous to ensure, by including carbon atoms in the base layer 3 in a concentration range greater than 1×10^{18} cm^{-3}, that the diffusion of the trivalent doping substance, in particular the diffusion of boron, is effectively reduced. In this way, the result can be achieved that the width of the base layer 3 can be reduced, thereby resulting

in a higher cut-off frequency. The inclusion of carbon atoms can take place, for example, via co-deposition of carbon during the epitactic growth of the base layer 3.